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## **Pulling all the pedagogic pieces together to provide good Electronic Feedback: an example from Science Education**

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### **Abstract**

*The aim of Nefreduca project was to develop digital science materials for chronically ill children and to assist them to cope more rationally with their illness. The Nefreduca system was developed in 2 stages. The first was a teaching-learning sequence about nutrition and kidney function, which was tested with the students and their teachers from the hospital school. The second phase was the construction of an automatic feedback system for Nefreduca. This paper reports the findings from both phases and makes the case that good feedback models must build upon on a good learning design that addresses students' misconceptions and introduces well structured e-activities*

Feedback is a topic that is on everyone's mind at the moment, not only researchers who are working towards the holy grail of automatic generated feedback but also tutors students and university policy makers. Our common goal is to support the student learning experience and there are many drivers influencing the production of fast efficient feedback The National Union of students have listed set of priorities for assessment feedback which should be timely and constructive while the findings

from the National students' survey also illustrates a need for prompt feedback. These results have prompted tutors to find more effective forms of electronic feedback; as illustrated by the examples generated by the Re-engineering Assessment Practices (REAP) project (Nicol 2007)

This paper will outline the main pedagogical drivers in the development of the Nefreduca program which was designed to provide a science based web teaching and learning sequence about nutrition and the kidney, targeted at lower secondary school children who are suffering from chronic kidney disease and who often spend long periods of time in hospital. It will discuss the modeling of the automatic feedback system in order to illustrate the need for not only cognitive support but also socio-emotive support in children that are trying to learn basic science concepts when suffering an illness.

## Background

Any one who misses school for any length of time has problems catching up with the curriculum, especially with science topics which are taught within a spiral developmental sequence (McDougall et al, 2004, Sobrino et al, 2001). This is especially problematic for children with a chronic disease, as they receive science enriched information from medical staff, throughout their illness and do not maintain a normal pattern of schooling. At the hospital they might have the support of a hospital teacher who is usually not a science specialist. A lack of science literacy can diminish the children's comprehension of their illness and effect their compliance with their recommended treatment, lifestyle and diet (Gutierrez et al, 2004; Arnau et al, 2005). Without an adequate science teaching-learning context in the hospital setting or at home when convalescing, these children often increase their medical vocabulary, without a clear understanding of its meaning (as we encountered when asking chronic sick children to explain briefly their illness or treatment) and are therefore unwittingly confounding the most basic of biological concepts.

Technology can offer a way to alleviate this particular problem especially for Catalan<sup>1</sup> school children (where this study was undertaken). A new educational initiative promoted by the Educational Department of Catalonia, called 'Projecte EDUCAT1x1' (Project 1:1) has been introduced to provide each child with a computer and a set of on-line text books and e-activities are being introduced into the school curriculum. This scheme provides an important driver to utilise technology in the home and in the hospital to support the learning of children who are suffering from a chronic illness. For this latter group the electronic materials may require more self regulated interactive activities accompanied by timely and appropriate feedback systems and so we embraced the technology to assist with the problem of teaching science to chronically ill children who do not have access to subject specialists when learning science. This approach raised a number of questions such as:

- How should we structure the materials?
- What findings would support the learning design process?

## The learning Design

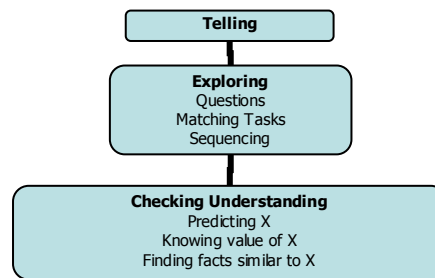
The design of the the Nefreduca materials has been based on the developmental research framework of Lijnse (1995) and the model "Tell, Explore, Check" (see figure 1) developed by Whitelock (1999) at the Open University. It has been used as the

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<sup>1</sup> Catalonia is one of the seventeen Autonomous Communities of Spain. It's in the northwest of the Iberian Peninsula.

basis to choose when and how to introduce the science concepts and relate them to the activities.

**Figure 1.** Tell Explore Check Model (T.E.C.)



The selection and scheduling of the biology content of the materials took into account the results of an initial *theoretical exploration* of the main difficulties encountered by students learning these types of concepts together with the pedagogical solutions found in the science education literature. The research of Clément (2003), Carvalho (2004) and especially the work of Arcà (2005), as well as the model-based teaching-learning approach introduced by Buckley (2000) influenced the selection of the final sequence of biology core concepts implemented in Nefreduca.

In order to adjust the science content to the hospital context, we undertook an empirical investigation with both the children and their teachers. We asked several children to write an account of their kidney disease, and to answer some biological questions about nutrition and the kidney. We also set up a number of informal meetings with the teachers about their visions for and barriers to teaching science in a hospital setting.

Finally with the information from both studies, we designed a first version of the Nefreduca program. Modifications were made after the system was used in anger. . For example, we added a new software component to collect the children's responses in the form of on-line drawings answers instead of written text. This reduced the cognitive effort of writing especially when the children wanted to work with the program in the dialysis room. (Saez, Whitelock and Pintó, 2009).

**Figure 2.** Screenshot of the beginning of Nefreduca



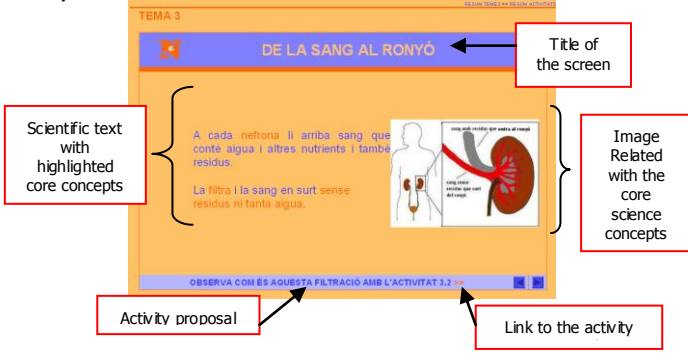


After several implementations and refinements to the science content, the activities and the ICT resources, following an agile methods approach, the final version was available for testing, (see table 1 below). Since this approach was people oriented rather than process oriented (Fowler, 2000) it facilitated the progressive adaptation

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to the hospital constraints as and when they were discovered by the software developer.

**Table 1.** Blocks of Nefreduca

<p><b>Introduction block</b></p> <p>Presents the learning objectives of the Nefreduca and an 'Initial questionnaire' to ascertain students' prior knowledge of the science before they worked through the program.</p> 	<p><b>Informatics management block</b></p> <p>Presents the instructions about how to use the program with its variety of ICT teaching resources (on-line questionnaires, animations, on-line image editors, videos and images).</p> 				
<p><b>The Science content block</b></p> <p>The science content holistically presents the origin and function of the nutrients found in the body cells, their transition from different "compartments" of the body and the waste produced from the body's use of these nutrients. The kidney function is just focused on its role in the excretion of metabolic waste products and water from the body, and consequently as the urine producer. The analogy between an organic and an artificial kidney is used to deal with the work of a dysfunctional kidney and its common treatment, the dialysis. The kidney function of secretor of several hormones has not been mentioned as it's not correlated with the biology secondary school curriculum. The science information is presents into four major themes which included:</p> <table border="1" data-bbox="240 1131 1353 1417"> <tbody> <tr> <td data-bbox="240 1131 794 1272"> <p><b>1.Food digestion and nutrient absorption:</b></p> <ul style="list-style-type: none"> <li>-Body exchange of substances with the environment</li> <li>-Nutrients as body matter and energy givers for daily activities</li> <li>-Food transformation to obtain nutrients (simple substances) in different digestive tract system</li> <li>-Movement of nutrients from the gut to the blood. Movement of waste to outside of the body</li> </ul> </td><td data-bbox="794 1131 1353 1272"> <p><b>2.Blood transport of nutrients and waste products:</b></p> <ul style="list-style-type: none"> <li>-Closed circuit of blood vessels – heart as pump for the blood movement</li> <li>-Blood as distributor of substances to body cells</li> <li>-Movement of nutrients and oxygen to inside the cells</li> <li>-Cell production of substances to grow and waste products</li> <li>-Movement of waste product from inside the cells to blood</li> </ul> </td></tr> <tr> <td data-bbox="240 1272 794 1417"> <p><b>3.Kidney excretion of waste products:</b></p> <ul style="list-style-type: none"> <li>-Normal number and position of the kidneys</li> <li>-Sections of the kidney and their function (filtering tubes and collector)</li> <li>-Physical characteristics of the filtering tubes (analogy with a strainer)</li> <li>-Filtration of waste products and water from the blood and production of urine</li> <li>-Movement of the urine from kidney to outside the body</li> </ul> </td><td data-bbox="794 1272 1353 1417"> <p><b>4.Kidney dysfunction and the role of dialysis:</b></p> <ul style="list-style-type: none"> <li>-Diagnosis by blood content or urine content or quantity produced daily</li> <li>-Sections and Connection between digestive system and blood system</li> <li>-Dialysis machine (artificial kidney) general parts and function- analogy with an organic kidney</li> </ul> </td></tr> </tbody> </table>		<p><b>1.Food digestion and nutrient absorption:</b></p> <ul style="list-style-type: none"> <li>-Body exchange of substances with the environment</li> <li>-Nutrients as body matter and energy givers for daily activities</li> <li>-Food transformation to obtain nutrients (simple substances) in different digestive tract system</li> <li>-Movement of nutrients from the gut to the blood. Movement of waste to outside of the body</li> </ul>	<p><b>2.Blood transport of nutrients and waste products:</b></p> <ul style="list-style-type: none"> <li>-Closed circuit of blood vessels – heart as pump for the blood movement</li> <li>-Blood as distributor of substances to body cells</li> <li>-Movement of nutrients and oxygen to inside the cells</li> <li>-Cell production of substances to grow and waste products</li> <li>-Movement of waste product from inside the cells to blood</li> </ul>	<p><b>3.Kidney excretion of waste products:</b></p> <ul style="list-style-type: none"> <li>-Normal number and position of the kidneys</li> <li>-Sections of the kidney and their function (filtering tubes and collector)</li> <li>-Physical characteristics of the filtering tubes (analogy with a strainer)</li> <li>-Filtration of waste products and water from the blood and production of urine</li> <li>-Movement of the urine from kidney to outside the body</li> </ul>	<p><b>4.Kidney dysfunction and the role of dialysis:</b></p> <ul style="list-style-type: none"> <li>-Diagnosis by blood content or urine content or quantity produced daily</li> <li>-Sections and Connection between digestive system and blood system</li> <li>-Dialysis machine (artificial kidney) general parts and function- analogy with an organic kidney</li> </ul>
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<p>Each theme presents the introduction of a set of discreet scientific concepts with text, images and/or flash animations and a series of activities which addressed the given concepts. In some theme templates there is a link to an activity where a video, animation or image presents some aspect of the digestive system, blood or excretory system function. Several questions are posed to the children in order to assess their comprehension of the science phenomena. ICT has been used specially to focus the attention or reinforce the idea of substances movement between "compartments". It has been avoided to focus on the learning of the anatomy rather than in the physiology.</p> 					

## Widening the knowledge about biology using Nefreduca

An evaluation of the Nefreduca program was undertaken with 32 sick children (10-16 years) who used those resources either in the hospital school, in their hospital rooms or in the dialysis room. The majority of the students involved in the study completed all the activities in 1hr to 1hr 30min.

We found that before using the system the children's ideas about the function of the kidney fell into four different hierarchical conceptions (see Whitelock et al., in press). These took the following forms (i.e. levels 1.1, 1.2, 2, 4):

**Table 2.** Hierarchical conceptions for the kidney function

<b>Level</b>	<b>Example</b>	<b>Before</b>	<b>After</b>
1.1 - Kidney as urine eliminator	<i>i.e. It makes you urinate</i>	8/32	-
1.2 - Kidney as a waste cleaner (from the blood or the body fluids)	<i>i.e. It cleans the blood; it purifies the body fluids</i>	14/32	-
2- Kidney as urine eliminator + waste cleaner (from the blood or the body fluids)	<i>i.e. It cleans the blood and makes me urinate</i>	9/32	-
3- Kidney as urine producer + blood waste eliminator	<i>i.e. The kidney eliminate the metabolism waste products of the blood</i>	-	4/22
4 - Kidney as urine producer + blood filter	<i>i.e. It filters the waste products of the blood and produce the urine</i>	1/32	18/22
<b>No answer</b>		-	11/32

Table 2 illustrates that during the first set of Nefreduca activities 70% (22/32) of the children view the kidney as an organ with just one function. That is the kidney just eliminates the urine (8/32) or cleans the waste from the blood (7/32) or body fluids (7/32). With the exception of only one, the remainder of the students (30%) attributed both functions to the role of the kidney in their own bodies. In this latter case, more students (6/32) referred to the kidney as a "cleaner of body fluids", and fewer (3/32) thought of the kidney as "cleaner of blood".

After using the Nefreduca program, the 22 children who were able to finish all the educational materials showed a change in their pre-conceptions of the kidney's functionality. They expressed a deeper understanding of how their kidney works on a daily basis and how it relates to others parts of their body. We found that in the end, all the students realised the relationship of the blood to the kidney and also that its main function was the production of urine. However we found different levels of comprehension for the process of filtration (see level 3 and 4).

The following account illustrates how the ideas of one student changed as he used the Nefreduca program.

A boy of 15 of years was hospitalised in the nephrology ward and started his dialysis treatment. The class session took place in the hospital school and was conducted by teacher "T2" (see Whitelock et al, in press). The student seemed to be calm and concentrated while using the digital materials. He even said that it was entertaining to use the computer for this type of work.

After answering the initial questions posed by the Nefreduca program, we classified his prior knowledge level at 1.1. Then, the student started to read the text for theme 1 (*Food digestion and nutrient absorption*) and accessed the activities. After the student viewed the video about the digestion-absorption process, he then started to answer a series of questions. When the student finished the activity 1a, he started to read and fill in the questions of activity 1B (see annex 1). In the end, the student was able to differentiate the two products of food transformation, which were the nutrients and the non-digested food. He said "we obtain the good nourishment or nutrients from the food".

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*that is chewed in the mouth and mixed with the acids of the stomach, and we send outside the body the bad nourishment or waste".* The student also demonstrated his knowledge of the nutrient absorption process which had previously been faulty. After saving his answers to the 1Bactivities, he began theme 2 (*Blood transport of nutrients and waste products*). He read the text from the WebPages and the teacher stated again that if he was unclear about anything, he should first revise what he had previously learned. Then he opened the link to activity 2 (see annex 1) that assessed his understanding of the exchange of materials from the blood to the body cells. An animation was used to explain these concepts and finally he understood the role the blood plays as a conveyor of nutrients and certain waste materials that can be eliminated by the kidney.

The student then moved to theme 3 (*Kidney excretion of waste products*). The teacher linked some of his symptoms (i.e. the increase in urine production) with one kidney function (to balance the body water). The teacher helped him to grasp the notion of filtration and why only certain substances are filtered by using the example of filtering the skin from hot milk. This analogy aided his understanding and he was able to identify correctly the path that the urine follows when it is eliminated from the body.

Near the end of the class session, the student started theme 4 (*Kidney dysfunction and the role of dialysis*) and he read for himself the on line text. The teacher praised him for his effort and stated that when he next received his dialysis session he would understand the process in more depth. He realised that if 'good things such as nutrients' were found in the urine it meant the kidney was not functioning correctly

Therefore by charting the student's answers from the activities in themes 1-4 we could see that he was able to relate both the urine content and its production to the digestive process. He achieved a "level 4" understanding at the end of his session with the Nefreduca program.

Only when we were confident that the Nefreduca learning design, which also included a set of appropriate assessment tasks, was suitable for this user group did we start to model the hospital teachers' feedback to the children.

### Modeling the teacher feedback

An ethnographic study was undertaken to investigate the feedback processes (both cognitive and affective) delivered by the hospital school teachers when using Nefreduca in a hospital setting (see Whitelock et al., in press).

The verbal interactions of three hospital school teachers from a Paediatric Hospital in Barcelona were audio recorded during five working sessions with the children. Several field notes of the non-verbal interactions were also recorded and informal interviews before and after the classes occurred were undertaken to gauge the teaching expectations for each session and also the students' cognitive and emotional states, during the lessons. All the teacher comments were coded with Bales' interaction categories (see table 3). This interactional framework was used since Whitelock et al (2003) has shown their use to be domain independent. In our case, all the comments could be coded with this set of categories. No comments fell into the D2 or D3 categories.

**Table 3. Bales' Interaction Categories**

Categories		Specific Examples
<b>Positive Reactions</b>		
A1	1. Shows solidarity	Jokes, gives help, rewards others
A2	2. Shows tension release	Laughs, shows satisfaction
A3	3. Shows agreement	Understands, concurs, complies, passively accepts
<b>Attempted Answers</b>		
B1	4. Gives suggestion	Directs, proposes, controls
B2	5. Gives opinion	Evaluates, analyses, expresses feelings or wishes
B3	6. Gives information	Orients, repeats, clarifies, confirms
<b>Questions</b>		
C1	7. Asks for information	Requests orientation, repetition, confirmation, clarification
C2	8. Asks for opinion	Requests evaluation, analysis, expression of feeling or wishes
C3	9. Asks for suggestion	Requests directions, proposals
<b>Negative Reactions</b>		
D1	10. Shows disagreement	Passively rejects, resorts to formality, withholds help
D2	11. Shows tension	Asks for help, withdraws
D3	12. Shows antagonism	Deflates others, defends or asserts self

We found that the teachers' feedback fell into two distinct phases when we observed the children using the Nefreduca program. These were:

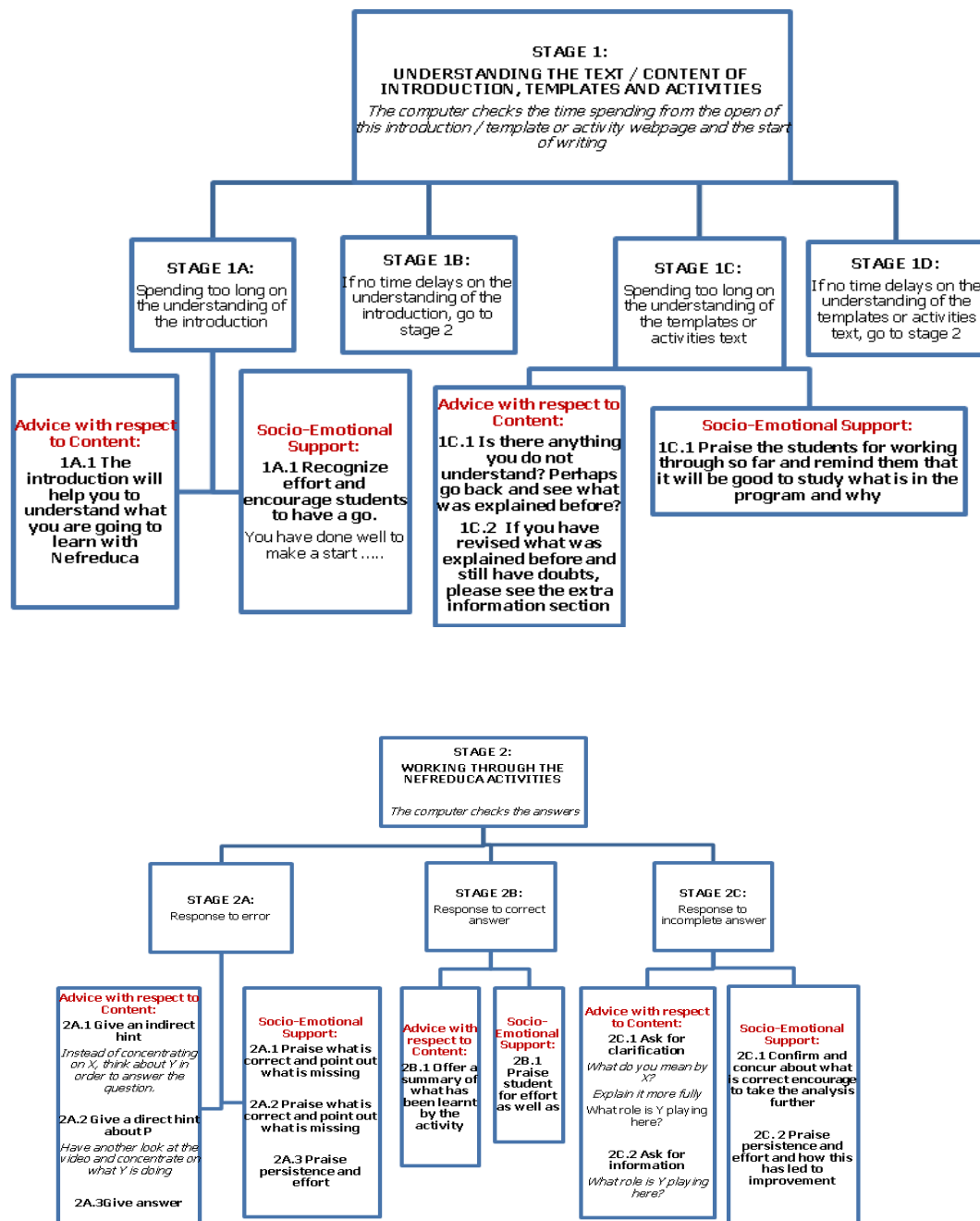
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*Stage 1:* Feedback with respect to time on the Nefreduca tasks and

*Stage 2:* Feedback to the answer provided by the student

An operational model for formative e-feedback generation is showed in figure 3 .The diagrams below illustrate a set of rules which can be used to generate the appropriate level of feedback and has been influenced by Anderson, Krathworld's (2000) revised Bloom's taxonomy.

**Figure 3.** Operational model of formative feedback generation for the next version of the Nefreduca program



Both the stage 1 and stage 2 operational models offer the user a combination of cognitive and socio- emotive feedback thus mirroring the findings from our empirical studies. If the child spends too long on one part of the Nefreduca program, the



computer for example can provide some motivational comments to encourage the sick child to continue with their studies even though they may be experiencing some lethargy due to their medication. This regularly happened on the ward and we have tried to model this type of teacher reaction. The model also provides hints to an incorrect answer. He asks for more clarification in an answer as well as always providing some form of socio-emotive support.

## Conclusions

The Nefreduca system was developed in 2 stages. The first being a teaching-learning sequence about nutrition and kidney function, which was tested with the students and their teachers from the hospital school. The second phase was the construction of an automatic feedback system for Nefreduca. Our findings suggest that cognitive change is possible when sick children use the Nefreduca program and that a realistic empirical modelling of appropriate feedback for this target group of users is best undertaken only when the learning design has been refined and tested. Socio-emotive feedback combined with cognitive hints and tips are essential components of this model and will be tested in the next phase of this research project.

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The Nefreduca project was funded by both local and national education departments. We would therefore like to thank the financial support received from the Consell Social de la Universitat Autònoma de Barcelona (UAB, Ref: Ref: 200700047154) and from the Ministerio de Educación y Ciencia (MICCIN, Ref: CCT005-06-00169).

### Annex 1

<b>Initial Questionnaire:</b> 1) Explain with your own words what do you think the kidney does?
<b>Activity 1A</b> Here, there a video where you could revise all your knowledge about the food digestion. Please after see the video as many times you need and then answer the questions. 1) Click the button to start the video. 2) Explain in different steps what happens to an orange juice and a cookie when they enter to our body. With which substances are they melt in each part of the digestive system? Use the below video images to help you.

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<p>3) Which are the two products obtained with the food transformation?</p>						
<p><b>Activity 1B:</b> We study now the nutrient transport from the small intestine to the blood that arrive to it.</p> <p>1) Please, view the animation to know more about this process and the elements that are involved. Notice the two body "compartments or spaces" that are involved: the small intestine and the blood. Click the button to start the animation.</p>						
						
<p>2) After the animation visualization, please answer the following questions:</p> <p>a) Which elements or substances get through the small intestine to the blood? Which do not get out?</p> <p>b) Which is the name for the movement of elements between this "compartments"?</p> <p>c) Where do you think will arrive the non-digested food?</p>						
<p><b>Activity 2:</b> We study the substances transport between the blood and the cells of all the body.</p> <p>1) Please, view the animation to know more about the elements that are involved in this process. Notice the two body "compartments or spaces" that are represented: the blood and the body cells.</p>						
						
<p>2) After the animation visualization, please answer the following questions:</p> <p>a) Which elements or substances do not get through the blood to the body cells? Which do it?</p> <p>b) What do the cells obtain from the elements or substances that enter to them?</p> <p>c) Which elements go out from the body cells to the blood? What does the blood with them?</p>						
<p><b>Activity 3a from theme 3:</b> We study now, how the filtration process is produced by the kidney. We want you to watch a video and an animation, and after that answer some questions.</p> <p>1) Click the button to switch on the video. Which element appears on it?</p>						
	<p>2) Look the animation to understand more about the filtration process. Click on the button to switch on.</p>					
						
<p>3) After using the animation, answer the following questions:</p> <p>a) Which elements or substances go out from the blood to the kidney (Filtering tubes and renal pelvis)? Which does not?</p> <p>b) Why can some elements or substances be filtered and others not? Think about how the structure of the filtering tubes.</p>						
<p><b>Activity 3b from theme 3:</b> Complete the sentences about the excretory-system filling in the gaps ..... with the icons that you think are necessary, and then put the sentences into a correct order than explains the full process.</p>						
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<p>The ureter connects the.....with the bladder.          The .....comes out of the..... through a ..... called the ureter.          The .....filters..... and ..... from the blood and forms the .....          The bladder works as .....where the....., is stored.          When the bladder is full, the.....goes out outside the body through a.....called the urethra</p>						
<p><b>Activity 4a from theme 4:</b> Imagine that you're in charge of analyzing a sample of pee and blood of a hospital patient. The first test result is that the pee contains substances the body needs and have come out.</p> <p>1) Explain how those substances might have arrived to the pee and why</p> <p>2) You know yet that the blood circulates to all parts of the body and gains and loss substances. So, if you suspect that a hospital patient has kidney problems, you could think that she/he might have more quantity of certain type of substances.          Do you know which substances could be? Why it could be possible?</p>						
						